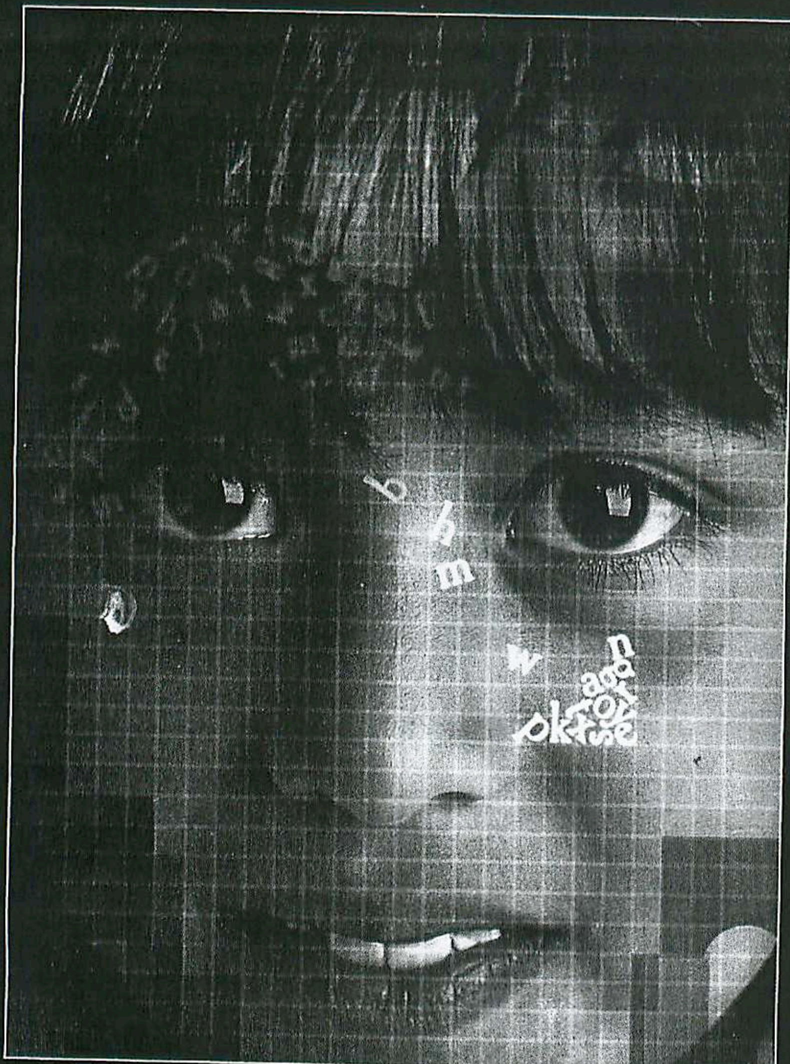
In Search of Understanding

The Case for Constructivist Classrooms



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Honoring the Learning Process

From the White House to the statehouse to the schoolhouse, politicians and educators have been wringing their hands over the condition of education in our nation. Some excoriate our present educational system, citing reports that raise questions about the inability of American students to perform as well on content area tests as students from other nations. Others are troubled by the condition of education in our nation for very different reasons. For a growing number of educators, questions regarding understanding and meaning and the roles that schools play in encouraging or stifling the search for understanding are far more important than questions regarding achievement as measured by test scores.

Many promising proposals have been put forth to address the issues surrounding students' construction of meaning. These proposals suggest overhauling assessment practices to make them more relevant for students, establishing site-based management teams in schools, rethinking the efficacy of tracking and ability grouping, and freeing school districts from federal and state mandates. We applaud these efforts, but find that these proposals don't quite go deep enough. They don't speak openly enough about the education system's underlying suppositions about what it means to learn, about what it means to become educated. They don't reach the nucleus of education: the processes of teaching and learning that occur daily, relentlessly, inexorably in classrooms throughout the nation. Educational reform must start with *how* students learn

and *how* teachers teach, not with legislated outcomes. After all, the construction of understanding is the core element in a highly complex process underpinned by what appears to be a simple proposition.

The Construction of Understanding

It sounds like a simple proposition: we construct our own understandings of the world in which we live. We search for tools to help us understand our experiences. To do so is human nature. Our experiences lead us to conclude that some people are generous and other people are cheap of spirit, that representational government either works or doesn't, that fire burns us if we get too close, that rubber balls usually bounce, that most people enjoy compliments, and that cubes have six sides. These are some of the hundreds of thousands of understandings, some more complex than others, that we construct through reflection upon our interactions with objects and ideas.

Each of us makes sense of our world by synthesizing new experiences into what we have previously come to understand. Often, we encounter an object, an idea, a relationship, or a phenomenon that doesn't quite make sense to us. When confronted with such initially discrepant data or perceptions, we either interpret what we see to conform to our present set of rules for explaining and ordering our world, or we generate a new set of rules that better accounts for what we perceive to be occurring. Either way, our perceptions and rules are constantly engaged in a grand dance that shapes our understandings.

Consider, for example, a young girl whose only experiences with water have been in a bathtub and a swimming pool. She experiences water as calm, moving only in response to the movements she makes. Now think of this same child's first encounter with an ocean beach. She experiences the waves swelling and crashing onto the shore, whitecaps appearing then suddenly vanishing, and the ocean itself rolling and pitching in a regular rhythm. When some of the water seeps into her mouth, the taste is entirely different from her prior experiences with the taste of water. She is confronted with a different experience of water, one

that does not conform to her prior understanding. She must either actively construct a different understanding of water to accommodate her new experiences or ignore the new information and retain her original understanding. This, according to Piaget and Inhelder (1971), occurs because knowledge comes neither from the subject nor the object, but from the unity of the two. In this instance, the interactions of the child with the water, and the child's reflections on those interactions, will in all likelihood lead to structural changes in the way she thinks about water. Fosnot (in press) states it this way: "Learning is not discovering more, but interpreting through a different scheme or structure."

As human beings, we experience various aspects of the world, such as the beach, at different periods of development, and are thus able to construct more complex understandings. The young child in this example now knows that the taste of seawater is unpleasant. As she grows, she might understand that it tastes salty. As a teenager, she might understand the chemical concept of salinity. At some point in her development, she might examine how salt solutions conduct electricity or how the power of the tides can be harnessed as a source of usable energy. Each of these understandings will result from increased complexity in her thinking. Each new construction will depend upon her cognitive abilities to accommodate discrepant data and perceptions and her fund of experiences at the time.

Student Learning in Schools

Accepting the proposition that we learn by constructing new understandings of relationships and phenomena in our world makes accepting the present structure of schooling difficult. Educators must invite students to experience the world's richness, empower them to ask their own questions and seek their own answers, and challenge them to understand the world's complexities. Duckworth (1993) describes her version of teaching thusly: "I propose situations for people to think about and I watch what they do. They tell me what *they* make of it rather than my telling them *what* to make of it." This approach values the students' points of view and attempts to encourage students in the directions they have charted for themselves. Schools infrequently operate in such a way, as they typically narrow the band of issues for students—and

teachers—to study, demand short and simple answers to questions, and present complexity as previously categorized historical eras, mathematical algorithms, scientific formulas, or pre-established genres and classes.

But schooling doesn't have to be this way. Schools can better reflect the complexities and possibilities of the world. They can be structured in ways that honor and facilitate the construction of knowledge. And they can become settings in which teachers invite students to search for understanding, appreciate uncertainty, and inquire responsibly. They can become constructivist schools. Noddings (1990) writes:

> Having accepted the basic constructivist premise, there is no point in looking for foundations or using the language of absolute truth. The constructivist position is really post-epistemological, and that is why it can be so powerful in inducing new methods of research and teaching. It recognizes the power of the environment to press for adaptation, the temporality of knowledge, and the existence of multiple selves behaving in consonance with the rules of various subcultures (p. 12).

Starting with What We Know

To effectively explore our educational system, we must first examine the core unit of the whole enterprise, the classroom, a setting we already know much about. First, the American classroom is dominated by teacher talk (Flanders 1973, Goodlad 1984). Teachers often disseminate knowledge and generally expect students to identify and replicate the fields of knowledge disseminated. In a flowchart of classroom communication, most of the arrows point to or away from the teacher. Student-initiated questions and student-to-student interactions are atypical.

Second, most teachers rely heavily on textbooks (Ben-Peretz 1990). Often, the information teachers disseminate to students is directly aligned with the information offered by textbooks, providing students with only one view of complex issues, one set of truths. For example, many teachers validate the textbook view of Christopher Columbus as an intrepid explorer in search of a new world. The revisionist view of Columbus' voyage as the cause of oppression of the Native-American population in North America is not frequently discussed in classrooms. Alternative interpretations of social phenomena are rarely considered.

Third, although there exists a growing interest in cooperative learning in America's schools, most classrooms structurally discourage cooperation and require students to work in relative isolation on tasks that require low-level skills, rather than higher-order reasoning. Think about, for example, the many elementary classrooms in which students sit alone for portions of almost every day completing workbook and ditto sheets.

Fourth, student thinking is devalued in most classrooms. When asking students questions, most teachers seek not to enable students to think through intricate issues, but to discover whether students know the "right" answers. Consequently, students quickly learn not to raise their hands in response to a teacher's question unless they are confident they already know the sought-after response. Doing otherwise places them at some risk.

Fifth, schooling is premised on the notion that there exists a fixed world that the learner must come to know. The construction of new knowledge is not as highly valued as the ability to demonstrate mastery of conventionally accepted understandings.

Perceived Success

The power and sanctity of the curriculum and the subordination of students' own emerging concepts are profound concerns. Many students struggle to understand concepts in isolation, to learn parts without seeing wholes, to make connections where they see only disparity, and to accept as reality what their perceptions question. For a good many students, success in school has very little to do with true understanding, and much to do with coverage of the curriculum. In many schools, the curriculum is held as absolute, and teachers are reticent to tamper with it even when students are clearly not understanding important concepts. Rather than adapting the curriculum to students' needs, the predominant institutional response is to view those who have difficulty understanding the unaltered curriculum as slow or disabled. These

students are often removed from mainstream classes, given remedial instruction, or retained.

Even students who are capable of demonstrating success, who pass tests with high marks and obtain "honors" diplomas, frequently don't connect the information they receive in school to interpretations of the world around them. Consider Gardner's (1991b) lament:

> I contend that even when school appears to be successful, even when it elicits the performance for which it has apparently been designed, it typically fails to achieve its most important missions. Evidence for this startling claim comes from a by-now overwhelming body of educational research that has been assembled over the last decades. These investigations document that even students who have been well-trained and who exhibit all the overt signs of success—faithful attendance at good schools, high grades and high test scores, accolades from their teachers—typically do not display an adequate understanding of the material and concepts with which they have been working (p. 3).

In many districts throughout the nation, students spend a good deal of time preparing for standardized tests or statewide exams. For example, in mathematics, a geometry teacher might help students memorize the formulas and proofs necessary to pass an exit or minimum competency exam. A few months later, however, when some of these same students are asked to apply geometric principles on a national examination, such as the National Assessment of Educational Progress (NAEP), only a small percentage of them might demonstrate the ability to do so (Schoenfeld 1988). In other words, although considered successful in a high school geometry course, many of these students cannot demonstrate facility with geometric principles, even when their learning was assessed in the same manner as it was previously assessed, specifically, on a multiple-choice exam.

Katz (1985) and Gardner (1991b) describe the discrepancy between perceived and actual success as the difference between learning and performance. In discussing this difference, Katz (1985) stresses that emphasis on performance usually results in little recall of concepts over time, while emphasis on learning generates long-term understanding. Students educated in a setting

that stresses performance learn that technique, rules, and memory matter more than context, authenticity, and wholeness. Therefore, rather than seeking deep understanding, these students seek short-term strategies for accomplishing tasks or passing tests. When asked, several weeks or months later, to apply what they supposedly had learned, most students can't.

Making a Difference

The debate that frames current conceptions of school reform was largely defined decades ago. Franklin Bobbitt (1924, p. 8) wrote: "Education is primarily for adult life, not for child life. Its fundamental responsibility is to prepare for the 50 years of adulthood, not for the 20 years of childhood and youth." The current critiques of American education emanating from business and industry certainly have their roots in Bobbitt's conception of the purpose of schooling. John Dewey (1938), however, argued that education as preparation for adult life denied the inherent ebullience and curiosity children brought with them to school, and removed the focus from students' present interests and abilities to some more abstract notion of what they might wish to do in future years. Dewey urged that education be viewed as "a process of living and not a preparation for future living."

Schools and the teachers within them can do both: they can be student-centered and successfully prepare students for their adult years by understanding and honoring the dynamics of learning; by recognizing that, for students, schooling must be a time of curiosity, exploration, and inquiry, and memorizing information must be subordinated to learning how to find information to solve real problems. Adult modeling and environmental conditions play a significant role in the development of students' dispositions to be self-initiating problem posers and problem solvers. When students work with adults who continue to view themselves as learners, who ask questions with which they themselves still grapple, who are willing and able to alter both content and practice in the pursuit of meaning, and who treat students and their endeavors as works in progress, not finished products, students are more likely to

demonstrate these characteristics themselves. Barzun (1992) writes:

> Anyone who has ever taught knows that the art of teaching depends upon the teacher's instantaneous and intuitive vision of the pupil's mind as it gropes and fumbles to grasp a new idea (p. 20).

Similarly, when the classroom environment in which students spend so much of their day is organized so that student-to-student interaction is encouraged, cooperation is valued, assignments and materials are interdisciplinary, and students' freedom to chase their own ideas is abundant, students are more likely to take risks and approach assignments with a willingness to accept challenges to their current understandings. Such teacher role models and environmental conditions honor students as emerging thinkers.

Considering Developmental Principles

Students' cognitive developmental abilities are another major factor in the process of constructing understanding. It is crucial that teachers have some understanding of the foundational principles of cognitive developmental theory. For example, in one kindergarten class, children watched their teacher mold three buckets of clay into eight balls each and give one ball to each child. Most of the students "correctly" counted the twenty-four balls and acknowledged that each child got a "fair" share. Did the students actually *know* that when the teacher divided the clay each ball became 1/8 of a bucket and 1/24 of the total amount of clay? They were in the room and they saw it happen. But, the children in this kindergarten class were intellectually busy grappling with other relationships and understandings. They were engaged in notions of counting, distributing, and matching, important undertakings in the development of their concepts of number. Most of them didn't consider the ball of clay 1/8 of one total and simultaneously 1/24 of another total. They did not construct the concept that fractions imply relativity. They *did* construct and consolidate many other concepts. They seriated numbers and established a

one-to-one correspondence between students in the class and balls of clay, constructions meaningful to them.

To maximize the likelihood that students will engage in the construction of meaning, teachers must interpret student responses in developmental terms and must appreciate those terms. For example, in discussing how children come to understand number, Papert (1988) writes:

> Children don't conceive number, they make it. And they don't make it all at once or out of nothing. There is a long process of building intellectual structures that change and interact and combine (p. 4).

Teachers who value the child's present conceptions, rather than measure how far away they are from other conceptions, help students construct individual understandings important to them.

The Simple Proposition Revisited

The proposition that we construct individual understandings of our world and the assertion that schools must play an important role in this process does sound simple. But what sounds simple propositionally is quite difficult operationally. Consider this example of a first-year middle school teacher preparing for opening day in a school noted for its constructivist orientation. Her journal entries describe her lesson planning process:

> *9/2*
> *Here it is, Labor Day, the day before I start my new job. I'm scared to death. Last week, I had a meeting with my team teacher. We talked about what we are going to teach for the first few weeks. It was very sketchy. She also talked about something called "the big picture." I'm not quite sure what she meant. She gave me an example. If only I could remember it now. We're starting the microscope unit. Oh, that's another thing. I always thought that we would just follow the textbook. She tells me to "start thinking in terms of units." If I could only get an opening to start this unit off with, I'd be a little more at ease.*

9/3
. . . Tomorrow with the kids I have to have a grabber lesson. Tomorrow, I'm THE TEACHER. My team teacher told me to get an idea of what the microscope unit is all about. Nothing has come to me yet. Perhaps, if I could only relax, I could think.

9/4
It happened! This morning around 4 a.m. I got an idea. A microscope "takes a closer look at life." My topic today was "Taking a Closer Look at Life." I paralleled a story about people wanting to take a closer look at what was happening at the scene of a fire to taking a closer look through a microscope lens. Not a very close analogy, but, in a sense, it worked. . . .

The teacher opened her first lesson with the question: What do you think life science is all about? A few students responded with one-word answers such as "living," "animals," "plants." She acknowledged each student with "Yes" or "That's right." She then read a story about a fire engine. Immediately upon finishing the story, she said to the students: "The point of the story is that you can see many things at a fire and you can see many things in science. Everyone come to the front and get your textbooks." After some administrative work took place, the teacher handed out photocopies of some well-known optical illusions and said: "In science, you have to develop a critical eye. Write down what you think you see." Her next questions were: "Who can see a vase?" and "Who can see two faces?"

The teacher's lesson plan had many of the elements of a constructivist approach, but her implementation of the plan did not. She opened the lesson with an umbrella question that asked students to share their current points of view. But she accepted one-word answers, asked for neither elaboration on the part of the speaker nor feedback from the group. She planned for an analogical discussion with students. But, she, herself, drew the analogy *for* the students rather than asking questions that would have allowed the students to generate their own analogies. She attempted to integrate her "science" topic with literature and art, encouraging the students to challenge their own perspectives. But *she* defined the range of perspectives by asking if the students saw

a vase or two faces before the students had time to determine for themselves what they were seeing.

The new teacher took delight in her generation of the "Taking a Closer Look" theme and designed a carefully structured plan to share her creativity. But, in doing so, she limited the students' opportunities to tap into *their* creativity. The lesson was not an invitation to explore the theme. It was a methodical telling of the theme.

This example suggests that becoming a constructivist teacher is not simple. It requires continual analysis of both curriculum planning and instructional methodologies during the process of learning to be a teacher, reflective practices for which most teachers have not been prepared.

Most teachers agree with the quests and goals of the constructivist orientation: teachers want students to take responsibility for their own learning, to be autonomous thinkers, to develop integrated understandings of concepts, and to pose—and seek to answer—important questions. Some teachers, though, have difficulty practicing constructivist methodologies. The pathway to becoming a constructivist teacher meanders through our own memories of school as students, our professional education, our deeply held beliefs, our most cherished values, and our private versions of truth and visions for the future. Bruner (1986) writes:

> "[W]orld making" . . . starting as it does from a prior world that we take as given, is constrained by the nature of the world version with which we begin the remaking. It is not a relativistic picnic. . . . In the end, it is the transaction of meaning by human beings, human beings armed with reason and buttressed by the faith that sense can be made and remade, that makes human culture and by culture, I do not mean surface consensus (p. 159).

It's important that we, together, explore the constructivist proposition and ways to put this proposition into practice.

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Considering the Possibilities

Contrasting Paradigms

Constructivism stands in contrast to the more deeply rooted ways of teaching that have long typified American classrooms. Traditionally, learning has been thought to be a "mimetic" activity, a process that involves students repeating, or miming, newly presented information (Jackson 1986) in reports or on quizzes and tests. Constructivist teaching practices, on the other hand, help learners to internalize and reshape, or transform, new information. Transformation occurs through the creation of new understandings (Jackson 1986, Gardner 1991b) that result from the emergence of new cognitive structures. Teachers and parents can invite transformations, but can neither mandate nor prevent them. For example, after gazing at a block of wood for the first three months of his life, an infant who touches the block with his newly acquired grasping skill transforms his cognitive structures, and thus affects his understandings of the block. Virtually all infants do this. On the other hand, many high school students read Hamlet, but not all of them transform their prior notions of power, relationships, or greed. Deep understanding occurs when the presence of new information prompts the emergence or enhancement of cognitive structures that enable us to rethink our prior ideas.

Why doesn't more thinking and re-thinking occur in schools? Our position is that the mimetic approach to education is too compelling for many educators to give up. It is amenable to easily

performed and widely accepted measurement, management, and accountability procedures. This approach has long dominated educational thinking, and, therefore, policymaking. If students can be trained to repeat specific procedures and chunks of information, then they are viewed as "having learned." The predominant ways in which students are asked to express this learning is through multiple-choice or short-answer tests. The typical manner in which teachers document this learning is through posting grades.

The constructivist vista, however, is far more panoramic and, therefore, elusive. Deep understanding, not imitative behavior, is the goal. But, capturing another person's understanding is, if anything, a paradoxical enterprise. Unlike the repetition of prescribed behaviors, the act of transforming ideas into broader, more comprehensive images escapes concise description. We see neither the transformed concept nor the process of construction that preceded its transformation. The only discernible aspect is, once again, the student's behavior, but a different type of behavior. In the constructivist approach, we look not for what students can repeat, but for what they can generate, demonstrate, and exhibit.

Traditional instruction often leads students to believe they are not interested in particular subject areas, such as physics or foreign language or literature. The constructivist paradigm holds disinterest less as a function of the particular subject areas than as a function of the ways in which students have been taught. Figure 2.1 summarizes some visible differences between traditional and constructivist learning environments.

Take, for example, two 7th grade science lessons on photosynthesis. In Mr. Randall's classroom, middle school science is taught through a combination of textbook work and teacher demonstration. Students perform experiments from time to time, depending upon the availability of materials and space. Students read a widely used 7th grade science textbook (Heimler, Daniel, and Lockard 1984), which explains that:

> Photosynthesis (foht oh sinh thuh sus) is the chemical change that produces food. In photosynthesis, carbon dioxide gas and water are combined to produce sugar and oxygen. The sugar may be changed to starch. Sunlight is necessary for photosynthesis. It supplies the energy for the chemical change. The energy becomes locked in the sugar and starch molecules that are produced (pp. 176).

Figure 2.1
A Look at School Environments

Traditional Classrooms	***Constructivist Classrooms***
Curriculum is presented part to whole, with emphasis on basic skills.	Curriculum is presented whole to part with emphasis on big concepts.
Strict adherence to fixed curriculum is highly valued.	Pursuit of student questions is highly valued.
Curricular activities rely heavily on textbooks and workbooks.	Curricular activities rely heavily on primary sources of data and manipulative materials.
Students are viewed as "blank slates" onto which information is etched by the teacher.	Students are viewed as thinkers with emerging theories about the world.
Teachers generally behave in a didactic manner, disseminating information to students.	Teachers generally behave in an interactive manner, mediating the environment for students.
Teachers seek the correct answer to validate student learning.	Teachers seek the students' points of view in order to understand students' present conceptions for use in subsequent lessons.
Assessment of student learning is viewed as separate from teaching and occurs almost entirely through testing.	Assessment of student learning is interwoven with teaching and occurs through teacher observations of students at work and through student exhibitions and portfolios.
Students primarily work alone.	Students primarily work in groups.

Mr. Randall then talks about the role of chlorophyll and presents the chemical equation for photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$. The written explanation of the chemical equation indicates that when carbon dioxide and water are in the presence of energy (sunlight, in the case of photosynthesis), sugar and oxygen are produced. The sugar is used by the plant to make the cellulose that forms its cell walls and to make food for self-repairs and storage for later nourishment. Mr. Randall also describes the process of respiration, then reviews the information through a test at the end of the chapter that includes several question formats:

- True or False: "Food is produced in leaves."
- Circle one: "(Carbon dioxide, Sugar, Water) is produced in photosynthesis."
- Fill in the Blank: "Photosynthesis occurs inside plant cells that contain ______________________________ ."
- Short answer: "How is respiration different from photosynthesis?" (pp. 183-185)

This is the mimetic approach to learning. Students commit new information to their short-term memory for the purpose of mimicking an understanding of photosynthesis on an end-of-chapter test. There is little in the presentation of the information or the assessment strategies that challenges students' current beliefs about the way plants grow and the relationships among plants and other life forms. In fact, both the way in which the content is presented and the manner in which learning is assessed militate against the development of such understandings, and instead encourage rote memorization of a symbolic, chemical equation.

Contrast this approach to a second classroom, one in which the teacher, Ms. Martina, not only deleted the molecular equation and references to cell walls in her introductory lesson plan, but actually deleted all references to photosynthesis. Ms. Martina asked her students to think of systems with which they might have some experience and familiarity, and to indicate the product created, the energy source needed, and the raw materials used. She asked her students to consider, for example, their art classes and what they create there. Several students taking a "home technologies" class at the time were making malted milkshakes. They combined ingredients (malt, milk, and cocoa) in the presence of an external energy source (an electric blender) to produce a product (the milkshake). They did not readily come up with a by-product. But when they lit on an "appetite-wetting aroma" as a possibility, they became quite animated. Another student, thinking of his health education class, described exercise as a system consisting of ingredients (a human body, weights, and exercise machines) acted on by an energy source (one's muscles) to generate a product (increased strength and muscle tone) and a by-product (a sense of well-being). These analogies generated enthusiasm about the students' home technologies and health class activities. The students engaged in interdisciplinary discussions with each other and Ms. Martina.

Ms. Martina structured her initial lessons on photosynthesis so that her students might consider and consolidate the aspects of a system. The term *photosynthesis* was not mentioned during the lesson. Barzun (1992) writes:

> It is not the subject but the imagination of [the] teacher and [the] taught that has to be alive before the interest can be felt (p. 63).

Ms. Martina asked her students to think of photosynthesis as a system in which certain ingredients (carbon dioxide and water) are changed by an outside energy source (sunlight) to produce a product (sugar) and a by-product (oxygen). The concept of a by-product, in and of itself, had been a new idea for most students and was an important precursor to understanding the "system."

It was important to Ms. Martina that her students consider the relationships among plants and other life forms and the role that photosynthesis plays in those relationships. The depth to which she might eventually pursue the chemical explanation of the topic depends on the strength of the framework the students construct as a result of the opening lessons.

Though Ms. Martina's students didn't construct a biochemical understanding of photosynthesis, and their examples were not completely analogous to the system of photosynthesis in terms of reversibility and complexity, they did begin to appreciate that one way of trying to understand photosynthesis is as a systemic process

yielding both a product and a by-product. This understanding can serve as a basis for the construction of a more sophisticated understanding of photosynthesis and the ability to use the unit's vocabulary. Forman and Kuschner (1977), in discussing Piaget's ideas on the construction of knowledge, write:

> Think of the child not understanding some system, such as the game of baseball, to understanding that system. Knowing the entire list of rules would not be credited as knowledge, to Piaget. Knowing how to navigate the rules, to infer why it makes sense to hit the ball lightly, to figure out why the rules allow you to run past first base but not second—these examples of a generative use of the rules give evidence that the list has been constructed into a whole system (p. 84).

Ms. Martina's analogic activity served as an invitation for students to look at photosynthesis as a whole system. The students' own creation of analogies helped them to construct a framework. In order to complete the task, students asked questions about photosynthesis, no mean feat with 7th graders, and struggled to put the "answers" into a meaningful context.

Let's consider students' conceptions of photosynthesis in a teacher preparation class of graduates and undergraduates with biology and earth science majors. In one class, the professor asked the students to explain the process of photosynthesis in "simple," everyday terms. The following two responses demonstrate the tentative nature of their understandings: "It has something to do with making carbon dioxide." "No. it's not. The plant uses carbon dioxide to make . . . to make . . . a food molecule . . . I think?"

These are two college students enrolled in both a biology course and a teacher preparation course. They acknowledged embarrassment at not being able to describe photosynthesis concisely. In fact, they volunteered to reconsider the topic and give the class a mini-lesson at the next class meeting. On that occasion, they accurately, and enthusiastically, described photosynthesis on the biochemical level. They used sketches and models of the light and dark stage reactions and the Calvin cycle and described in detail the many molecular activities that take place during photosynthesis.

During the students' description of how chlorophyll gives off electrons, another class member asked, "Does the chlorophyll ever run out of electrons?"

After a contemplative pause, one of the presenters replied, "No, it has lots of them."

These two students offered the class a technically accurate description of photosynthesis. They demonstrated that they had the ability to memorize and recall information, and that they could effectively articulate this information to others. But they did not direct questions back to the information they had memorized. In other words, they had prepared their presentation as if they were about to take a fact-based, multiple-choice test.

Let's look at an excerpt from the journal of another student in the same methods class:

> Unfortunately, one of the lasting impressions I will have from this class was the series of disappointing responses I heard to your questions about photosynthesis. Clearly, most students in the class, aside from not remembering the details of photosynthesis (to some degree forgivable), were apparently not taught or made to appreciate its significance to life on this planet, energy flow through the food chain, atmospheric composition, and the elegant efficiency with which solar radiation is utilized by chlorophyll. I don't think you intended to make photosynthesis the topic by which you demonstrated the deficiencies of our educational system. However, that's how it turned out. The people in our class are reasonably intelligent. The limited understanding of a basic concept like photosynthesis, demonstrated this week, can only be the result of inadequate teaching. And, I suppose, it is this that we've been considering all along. (Ferrandino 1991)

Choosing the Constructivist Paradigm

When teachers recognize and honor the human impulse to construct new understandings, unlimited possibilities are created for students. Educational settings that encourage the active construction of meaning have several characteristics:

• They free students from the dreariness of fact-driven curriculums and allow them to focus on large ideas.

• They place in students' hands the exhilarating power to follow trails of interest, to make connections, to reformulate ideas, and to reach unique conclusions.

• They share with students the important message that the world is a complex place in which multiple perspectives exist and truth is often a matter of interpretation.

• They acknowledge that learning, and the process of assessing learning, are, at best, elusive and messy endeavors that are not easily managed.

To understand constructivism, educators must focus attention on the learner. But, opportunities for learners to learn are heavily controlled by the structure of schools. This book, therefore, often chronicles examples of teaching/learning interactions from the point of view of the teacher and the setting for the purpose of illustrating how the "people in charge" might begin to restructure the learning opportunities they make available in their settings. But we must *always* remember that in order to realize the possibilities for learning that a constructivist pedagogy offers, schools need to take a closer, more respectful look at their learners.

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3

Coming To Know One's World

Constructivism, as a way of coming to know one's world, is supported by a long and honorable body of literature and research, much of which is listed in this book's bibliography. We highlight here the works of a few philosophers, researchers, and theorists who have informed our thinking and practice and whose work underpins the constructivist teaching principles and descriptors we discuss in Parts II and III. There is clearly a connection between constructivism as an epistemological and philosophical image and constructivism as an educational framework.

Although some argue that the first great documented constructivist was Socrates, our discussion doesn't stretch that far back. In the more recent past, several philosophers, psychologists, and educators have struggled to understand the individual's relationship with nature and society and have helped us reformulate many of the fundamental questions we have asked ourselves. The nature of knowledge, and therefore of learning, has emerged over time as an essential line of inquiry.

The philosopher Emmanuel Kant, whose work bridged the 18th and 19th centuries, attempted to wed two disparate views of knowledge: the view that logical analysis of actions and objects leads to the growth of knowledge and the view that one's individual experiences generate new knowledge. Kant contended that both views have merit: analysis, by definition, occurs after the fact; sensate experiences occur before or during the event. Both are a

function of one's own idiosyncratic mental filtering system. Kant concluded that one cannot infer new relationships among objects, events, or actions unless one has a priori views through which perceptions can be organized. These views affect how one makes sense of new information. Bruner (1986, p. 96) referred to these prior understandings as "mental constructions projected onto an 'objective world.'"

What Is Real?

One cannot have an interest in the notions of constructivism without grappling with questions of perception and reality. Is there one, fixed, objective world that we all struggle to come to know, or are there many different worlds, dependent for their definition upon individual perception? The psychologist George Kelly (1955) wrote of the relationship between perception and objective reality:

> Man looks at this world through transparent patterns or templets, which he creates and then attempts to fit over the realities of which the world is composed. The fit is not always very good. Yet, without such patterns the world appears to be such an undifferentiated homogeneity that man is unable to make any sense out of it. Even a poor fit is more helpful to him than nothing at all (pp. 9-10).

We concur. We once watched a seven-year-old child at the beach for the first time. When she first stepped off of the boardwalk, she exclaimed with great surprise and discomfort, "The sand sticks between my toes!" We brushed the sand away and she happily took another step, then disappointedly said, "It keeps on happening." She made many other discoveries that day, a good number of which did not "fit" with her prior experiences.

Idiosyncratic constructions of prior experiences form the basis of the paradigms, the frameworks of thinking, we each use to perceive and consider the phenomena around us. Kuhn (1962), in his classic work, *The Structure of Scientific Revolutions*, uses the term "paradigm" to describe the lens that orders, but also limits, our perception and thinking. He uses the term "paradigm shift" to refer to the process that occurs within the individual who is able

and willing to change his lens. Changing the lens is an internal process initiated by the individual when current rules and theories about the way one's world works no longer account for the information being perceived or provide for the job to be done.

For many educators, becoming a constructivist teacher requires a paradigm shift. Becoming such a teacher means much more than appending new practices to already full repertoires. For many, it requires the willing abandonment of familiar perspectives and practices and the adoption of new ones.

The Influence of Piaget

Kuhn's paradigm shift is similar to the description of accommodation offered by the well-known Swiss scholar, Jean Piaget, one of the most influential proponents of constructivism. Piaget was, by his own definition, a genetic epistemologist concerned primarily with cognitive development and the formation of knowledge. His research led him to conclude that the growth of knowledge is the result of individual constructions made by the learner. Piaget (1971) wrote late in his career:

> The current state of knowledge is a moment in history, changing just as rapidly as knowledge in the past has changed, and, in many instances, more rapidly. Scientific thought, then, is not momentary; it is not a static instance; it is a process. More specifically, it is a process of continual construction and reorganization (pp. 1-2).

Although Piaget's career spanned over 50 years and generated an extraordinarily substantive body of research, his work has gained varying levels of acceptance in American education circles. There are many reasons for this, not the least of which is Piaget's own reluctance to apply his notions to education. Another reason lies in the strong roots of American behavioral psychology in our educational system, exemplified by the work of Skinner (1938) and Thorndike (1926). These theorists and researchers described human behavior essentially by the stimulus-response relationship coupled with positive reinforcement of desired behaviors and

negative reinforcement of unwanted behaviors. Other views of human behavior have been largely ignored in American education. Wadsworth (1971) writes:

> Traditionally, American psychologists of the behaviorist school do not infer the existence of internal mental processes (of thought). Piaget's concepts, like assimilation, are entirely foreign to the behaviorist position (p. 6).

Piaget viewed constructivism as a way of explaining how people come to know about their world. He buttressed this explanation with extensive documentation of behaviors he witnessed and with well-supported inferences about the functions of the mind. Piaget (1952) viewed the human mind as a dynamic set of cognitive structures that help us make sense of what we perceive. These structures grow in intellectual complexity as we mature and as we interact with the world we come to know and as we gain experience. Through maturation and experience, the groundwork for new structures is laid. For example, the cognitive structures required to comprehend that a wooden cube is hard are rudimentary and far less complex than the structures necessary to understand that a cube has length, width, and height, and that these three factors combine to determine the cube's volume.

An infant, yet unable to hold or manipulate the cube, defines it by the sides visible to her at that point in time. When the child's musculature and mental structures allow her to touch it, she is presented with new information that must be integrated into her thinking. An important cognitive structure has changed; the initial "nongrasping" structure has been refashioned into a new "grasping" one. This process is called accommodation. The child's newly created structure allows assimilation of the experience to occur within her mind.

In Piagetian terms, the temporary cognitive stability resulting from the balance of assimilation and accommodation is called equilibrium. Piaget suggested that the creation of new cognitive structures springs from the child's need to reach equilibrium when confronted with internally constructed contradictions; that is, when perception and "reality" conflict. The quest for cognitive equilibrium is among the most controversial of Piaget's notions.

Bruner (1964) and Chomsky (1977) have suggested that factors such as language and prior experience are more closely associated with the development of new structures than is the quest for cognitive equilibrium. A number of other cognitive theorists and researchers (Case 1985, Haroutunian 1983, Gardner 1991b) have also challenged Piaget's assertion that the quest for cognitive equilibrium generates the development of new mental structures. We believe that neither his earliest notions of stage theory nor a generalized view of the relationship between the person and his world do much to inform educational practice (see Chapter 7). However, we are still drawn to and have been influenced by his later work. The more Piaget came to understand human growth and development, the less he focused on group-driven conceptions of human cognition and the more he offered to educators. Fosnot (in press) writes of Piaget's later career refinements:

> [Piaget's] theory went through radical reformulation in the ten years prior to his death. In those years he moved away from a simplistic discussion of assimilation, accommodation, and static equilibrium, offering instead a model of dynamic equilibrium characterized by successive coordination and progressive equilibrations. He moved away from a static stage theory (preoperational, concrete, formal) toward a delineation of the successive possibilities and logical necessities generated by subjects as they attempted to explore and understand various problems (p. 7).

Piaget's ground-breaking work spawned an avalanche of theories and research studies, greatly altering cognitive psychology. In our view, the face of what education can be has been changed as well, but educators have not been looking into the mirror.

Discrepancy Resolution

Constructing understandings of one's world is an active, mind-engaging process (Sigel and Cocking 1977, Von Glasersfeld 1981). While it is true that, as learners, we all take in some information passively, the constructivist perspective suggests that even this information must be mentally acted upon in order to have meaning for the learner. Copple, Sigel, and Saunders (1984) highlight the

role of discrepancy resolution as perceived by the learner in the construction of knowledge. They discuss the well-known experiment in which a student observes two identical glasses of water filled to the same point and then observes the contents of one glass emptied into a tall, narrow beaker and the contents of the other glass emptied into a short, wide beaker. Young students usually assert that, even though they saw that the amount poured into each of the beakers was identical, the tall, narrow beaker now contains more water than the short, wide one. No amount of teaching, they contend, will alter the students' conceptions. They ask, rhetorically:

> Does the child need to learn to observe the containers more carefully, or perhaps watch more closely when the water is being poured? Does she need to have the water reversed and then repeated until she sees the equivalence (pp. 18)?

Sigel and Cocking (1977) assert that students' fundamental quest is discrepancy resolution. The student who perceives that the two initial glasses held equal amounts of water and the two subsequent beakers did not has no discrepancy with which to contend. In this student's world, defined, in part, by the cognitive structures available to her at that point in time, there is nothing discrepant about equals becoming unequal. However, the student who recognizes that equals must remain equal, even if the receptacles in which they are held change shape, has a discrepancy to resolve. Typically, the discrepancy is resolved by the student incorporating a greater number of variables and new information into her analysis. This is not to say that she will necessarily construct the understanding held by the teacher or other thinkers in the class, just that the new understanding will likely be somewhat more sophisticated than the prior one.

What constitutes sophistication is quite relative and contextual, however. Consider the following example. One cold winter morning, sitting in the car at a red light, a three-year-old child noticed a crossing guard in the intersection walking away from him. The guard was wearing a regulation uniform with the bulky long coat, white gloves, and white, close-fitting hood. In great surprise, the child exclaimed, "Look, there's a snowman crossing the street!" He then added, "I didn't know snowmen were real."

This three-year-old had broadened his "snowman" concept from storybook characters and snowday sculpturing to "real" ones

that walk across streets. He experienced cognitive conflict: snowmen aren't alive, but in front of him was one crossing the street. His resolution of the conflict, his more "sophisticated" idea that snowmen are real, which satisfied him at the time, remained until further information and experiences prompted his re-thinking of this understanding. Was this child's "real snowmen" understanding errant? According to the American College Dictionary (1963, p. 408), errant means "journeying or traveling, as a medieval knight in quest of adventure." In his public radio broadcast, John Lienhard (1993) said, "Five hundred years ago, . . . [a] person in error was a person searching for the truth."

The Need to Find One's Own Problem

Many 8th and 9th graders throughout the nation take algebra. A common problem they are asked to solve is:

> Point A and Point B are 250 miles apart. A train leaves Point A heading for Point B at 11:00 a.m. travelling at 55 MPH, and another train leaves Point B heading for Point A at 11:30 a.m. travelling at 60 MPH. At what time and at what point will they pass one another?

Adults with whom we work still groan at the mention of those trains. As 8th grade students, most of them answered this sort of question correctly on exams because they memorized the appropriate formal equations and applied them when confronted with the problems. But for most, no new understandings of time and rate functions were constructed, and the equations were quickly forgotten once the exams were completed.

Although designed to foster students' algebraic skills, these types of textbook problems often interfere with students' desire to engage in future mathematical endeavors and, over time, erode students' confidence and self-esteem. The line between cognitive dissonance, which can provoke a student's desire to persevere, and intrapersonal frustration, which interferes with the student's desire to resolve dissonance, is a fine one that is often difficult to recognize. To foster the development of students' abilities to organize and understand their individual worlds, teachers need to encourage students to find their own problems.

Coming to know one's world is a function of caring about one's world. Caring about one's world is fostered by communities of learners involved in trying to answer similar, but not necessarily identical, problems. The energy necessary for construction of problem solutions demands commitment. Commitment, in turn, emanates from construction. An engineer watches a newly designed airplane execute a flawless performance and says, "That's my baby!" An architect, after years of long hours working on a blueprint for a complex structure, says, "That's my baby!" A father, at his daughter's black belt karate exhibition says, "That's my baby!" Why the same metaphor? There is a commitment inherent in parenting, an activity that includes design, investment, joy, and pain. Indeed, other activities high in these qualities engender great commitment as well.

Designing, thinking, changing, evaluating—most particularly in response to a felt need—create interest and energy. Cognitive processes work to address affectively driven issues. Helping students or groups of students to clarify for themselves the nature of their own questions, to pose their questions in terms they can pursue, and to interpret the results in light of other knowledge they have generated is the teacher's main task.

The Challenge

Piaget (1969) wrote:

> The heartbreaking difficulty in pedagogy, as, indeed in medicine and in many other branches of knowledge that partake at the same time of art and science, is, in fact, that the best methods are also the most difficult ones: it would be impossible to employ a Socratic method without having first acquired some of Socrates' qualities, the first of which would have to be a certain respect for intelligence in the process of development (p. 69).

A constructivist framework challenges teachers to create environments in which they and their students are encouraged to think and explore. This is a formidable challenge. But to do otherwise is to perpetuate the ever-present behavioral approach to teaching and learning.

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